## REMARKS

This Reply is timely filed and responsive to the Final Office Action mailed March 9, 2006 ("Final Office Action"). Claims 1-4, 6-14 and 16 were pending at the time of the Office Action. In this Reply, no claims have been amended or cancelled. No new matter has been added.

In the Final Office Action, the Examiner rejected claims 1-4, 8, 11-14 and 16 under 35 U.S.C. §103(a) as being unpatentable over Kruger (U.S. 6,104,942) in view of Van Veen *et al.* (U.S. Patent Publication No. 2003/0088180). According to the Examiner:

> Kruger teaches a method of and apparatus for examining biological tissue including radiating a region of tissue with microwave radiation pulses that span a range of microwave frequencies, where the tissue region emits thermoacoustic signals responsive to the microwave pulses that are received by an acoustic transducer array that may be mechanically moved, which then provides electrical signals in response, and where the radiation pulses are produced by at least one antenna and include a plurality of polarizations, and forming at least one image of the tissue region from the thermoacoustic signals, where the at least one image comprises a plurality of images from fractional portions of the tissue that are combined to form an overall image (col. 1, lines 13-15, col. 3, lines 1-30, col. 4, lines 3-32, 42-51 and 63-67, col. 5, lines 1-45 and 60-67 and col. 6, lines 1-7). Kruger does not explicitly teach that the range of microwave frequencies is at least 600 MHz or at least 1 GHz, that the tissue region is breast tissue and that the at least one antenna is a horn antenna.
>
> In the same field of endeavor of microwave imaging of tissue, Van Veen et al. teaches the use of ultrawideband microwave frequencies to image breast tissue, where the microwave radiation is produced by a horn antenna (paras. 3, 5, 29 and 43). Although Van Veen et al. uses

the applied microwave radiation for traditional microwave imaging by receiving the microwave energy reflected by the tissue, the application of microwave energy would inherently cause the heating of tissue that produces the thermoacoustic signals as in Kruger. Thus, one of ordinary skill in the art would understand that the radiation applied by Van Veen et al. could be used for thermoacoustic imaging. Further, it would have been obvious to one of ordinary skill in the art at the time of the invention that applying a wider range of frequencies results in more information collected, and thus improved images of the tissue. As Kruger teaches the application of microwave energy swept across a range of frequencies, it would have been obvious to use the ultrawideband frequencies of Van Veen et al. in order to maximize the detail in the information collected.

Applicants respectfully disagree with the characterization of the Kruger reference as well as the obviousness rejection asserted above. However, before reviewing the claim rejections based on cited art, Applicants will review the claimed invention as recited in claim 1.

Amended claim 1 recites a method of examining biological tissue, and includes the steps of radiating a tissue region with a plurality of microwave radiation pulses which span a range of microwave frequencies of at least 600 MHz, wherein the tissue region emits a plurality of thermoacoustic signals in response. At least one image of the tissue region is then formed from the plurality of thermoacoustic signals. Complementary related system claim 11 recites a system for examining biological tissue, comprising a microwave radiation source for radiating a tissue region with a plurality of microwave radiation pulses, the plurality of radiation pulses spanning a range of microwave frequencies of at least 600 MHz, wherein the tissue region emits a plurality of thermoacoustic signals responsive to the microwave pulses, an acoustic transducer array for receiving the thermoacoustic signals, the transducer array providing electrical signals in response

thereto, and an imager for forming at least one image of the tissue region from the electrical signals.

Applicants note that the claimed method and system relate to *thermoacoustic imaging* which is based on analysis of induced *acoustic* (sound) waves, which is highly distinct in both physics, methodology as well as required instrumentation as compared to conventional microwave imaging. In conventional microwave imaging, such as disclosed in the cited Van Veen reference, microwave irradiation induces reflected microwave signals from the irradiated tissue (e.g. breast tissue) which is received by an antenna which converts the emanated electromagnetic (microwave) signal to an electrical signal. In contrast, in the claimed thermoacoustic imaging, microwave irradiation is used which induces the irradiated tissue to emanate thermoacoustic signals which are collected by an acoustic transducer, such as a piezoelectric based transducer array 125 which converts the sound waves to an electrical signal.

As noted above, in thermal acoustics, it is the conversion from EM energy to ultrasound energy that is used for imaging. Because of this conversion in the form of energy, increasing the bandwidth of the stimulating electromagnetic radiation does not improve resolution because it is the transducer array's aperture that determines the resolution in thermal acoustics. The exact impact of trying a wide range of frequencies was unknown for thermal acoustic imaging prior to the present invention, except for the obvious computational complexity which by itself would strongly teach way from its consideration (See also the teachings of the cited Kruger reference, described below).

Specifically, the data set provided by stimulating electromagnetic radiation over the claimed ultrawideband range of frequencies according to the invention is clearly quite large as compared to the data provided by conventional single frequency stimulation. For processing such

data, the application describes methods for the highly complex task of forming images from such a large amount of data, such as using a *significant and non-obvious modification* of a preferred adaptive beamformer, the Robust Capon Beamformer (RCB). The original RCB is disclosed in an article by inventor Jian Li and Z. Wang entitled "On robust Capon beamforming and diagonal loading. Specifically, the inventors discovered how to utilize the large data set collected from a plurality of different stimulating frequencies, such as to form a single image, using a modified RCB, as described in paragraph 62 (copied below).

[00062] Application specific factors for thermoacoustic imaging according to the invention require extending the RCB algorithm to wideband signals. As disclosed in U.S. Application No. 10/358,597, the RCB algorithm is generally described for narrowband signal. To extend the RCB for application to wideband signals, a wideband signal can be divided into several narrowband frequency bins, and the RCB applied to each bin. Thus, the relatively wideband thermoacoustic signal can be treated as comprising a plurality of narrow pulses with the arrival time and pulse duration approximately known. Through time gating, a large portion of signal interferences can be removed before applying the RCB.

Turning now to the cited art, the primary cited reference, Kruger, discloses methods and apparatus for measuring and characterizing the localized electromagnetic wave absorption properties of biologic tissues *in vivo*, using incident electromagnetic waves to produce resultant acoustic waves. The tissue is exposed to modulating electromagnetic radiation, to produce modulating acoustic signals. The modulating acoustic signals are detected by an acoustic sensor which is primarily sensitive to acoustic radiation at a focal point distant from the sensor. Multiple measurements from multiple different focal points can then be combined into an image, *or* measurements at the same focal point at different excitation frequencies can be combined to produce an absorptivity spectrum for the tissue, either of which may be used for medical diagnostic purposes.

The first Kruger embodiment (thermoacoustic) is a method of imaging tissue structures from localized absorption of electromagnetic waves, by irradiating the tissue with *continuously*

*modulating electromagnetic radiation*, and detecting the resulting acoustic waves as disclosed in col. 3 lines 12-21:

Specifically, in one embodiment, the invention features a method of imaging tissue structures from localized absorption of electromagnetic waves, by irradiating the tissue with continuously modulating electromagnetic radiation, and detecting the resulting acoustic waves with an acoustic sensor which is primarily sensitive to acoustic radiation at a first focal point distant from the sensor. The sensor is used to collect data from two or more different locations in the tissue, and this data is combined to produce an image of structures in the tissue.

The second Kruger embodiment (absorption spectrum) uses continuous, frequency modulating electromagnetic radiation generated by the source, and the resultant pressure waveforms arriving at the acoustic sensor from the focal point, are compared to the frequency of the electromagnetic radiation, to form a measure of the absorptivity spectrum as disclosed in col. 3, lines 22-30:

In a second embodiment, a similar apparatus is used in characterizing tissue at a focal point of the acoustic sensor. In this embodiment, continuous, frequency modulating electromagnetic radiation is generated by the source, and the resultant pressure waveforms arriving at the acoustic sensor from the focal point, are compared to the frequency of the electromagnetic radiation, to form a measure of the absorptivity spectrum of tissue located at the focal point of the acoustic sensor.

Col. 5 line 60 to col. col. 6, line 7 of Kruger is copied below:

In use, the focus point of transducer 30 may be scanned about the inside of the tissue sample 24, while collecting signal amplitude data from amplifier 34. The amplitude data can then be plotted as a grey-scale as a function of focal point position to form a two- or three-dimensional image of the tissue structures. Alternatively, if the microwave frequency is swept slowly (compared to tau) over time across some range of values while the focal point is maintained, an absorption spectrum for the tissue at the focal point of the transducer will be generated over time. This spectrum can be displayed by PC 38 on display terminal 40 and used to characterize the tissue at the focal point. These techniques can be combined to generate two- or three-dimensional images reflecting absorptivity spectra at multiple focal points.

Kruger thus teaches a first (thermoacoustic) and a second embodiment (absorptivity spectra) for imaging. Although the Examiner asserts that Kruger "teaches a method and apparatus for examining biological tissue including radiating a region of tissue *with microwave*

*radiation pulses that span a range of microwave frequencies*", Applicants respectfully point out that Kruger does not disclose or suggest use of irradiating *pulses*. In both embodiments, Kruger discloses continuous periodically modulated radiation, such as sinusoids, as opposed to pulses. Moreover, Kruger teaches away from using irradiating pulses by noting the continuously periodically modulated radiation "substantially increase[s] the signal-to-noise ratio of the recorded signal, reduce[s] the power requirements of the radiation source, and simplify[ies] the reconstruction methodology and the complexity of the associated apparatus". This is clearly noted in col. 2 line 66 to col. 3 line 11 (copied below; see also col. 8, lines 32-48):

> The present invention improves upon what is disclosed by Bowen and in the above-referenced U.S. Patent Application in several ways. First, the present invention uses *continuous, periodically modulated radiation in place of narrowly pulsed radiation.* Continuous radiation can be used to stimulate sonic waves continuously without having to wait for sequences of pulses. The localizing method for reconstructing uses constructive and destructive interference of periodic sonic waves generated by the *continuous radiation*. This approach can substantially increase the signal-to-noise ratio of the recorded signal, reduce the power requirements of the radiation source, and simplify the reconstruction methodology and the complexity of the associated apparatus.

Since Kruger teaches continuous radiation "can substantially increase the signal-to-noise ratio of the recorded signal, reduce the power requirements of the radiation source, and simplify the reconstruction methodology and the complexity of the associated apparatus" as compared to pulsed radiation, Kruger clearly teaches away from pulsed based methods, such as claimed by Applicants.

Forgetting for the moment regarding Kruger's clear failure to disclose pulse irradiation and Kruger's teaching away from the same, as noted above, the Examiner attempts to make up for Kruger's deficiency with regard to Applicants' claimed method of examining biological tissue comprising use of a "plurality of microwave radiation pulses, said plurality of radiation pulses

spanning a range of microwave frequencies of at least 600 MHz" for stimulating the tissue, with Van Veen.

Van Veen discloses microwave imaging via space-time beamforming carried out by transmitting microwave signals from multiple antenna locations into an individual to be examined and receiving the backscattered (reflected) microwave signals at multiple antenna locations to provide received signals from the antennas. The received signals are processed in a computer to remove the skin interface reflection component of the signal at each antenna to provide corrected signal data. The corrected signal data is provided to a beamformer process that time shifts the received signals to align the returns from a scatterer at a candidate location, and then passes the time aligned signals through a bank of filters, the outputs of which are summed, time-gated and the power therein calculated to produce the beamformer output signal at a candidate location. The beamformer is then scanned to a plurality of different locations in the individual by changing the time shifts, filter weights and time-gating of the beamformer process. The output power may be displayed as a function of scan location, with regions of large output power corresponding to significant microwave scatterers such as malignant lesions.

Applicants note that ultra wideband microwave stimulation disclosed by Van Veen is well-known in the radar community. In Van Veen, it is the microwave reflected wave that is used to form tumor images. Van Veen thus clearly relates to conventional microwave imaging where microwaves are both transmitted and received. In the Van Veen reflection-based approach, the wider the bandwidth, the better the range resolution. As noted above, for thermal acoustics as disclosed in one Kruger embodiment (and the claimed invention), it is the conversion from EM energy to ultrasound energy that is used for imaging. Because of this, increasing the bandwidth of the stimulating radiation in thermal acoustics does not improve image resolution. Accordingly,

the Examiner's asserted motivation for using Van Veen's ultrawide pulses with Kruger's invention by "applying a wider range of frequencies results in more information collected, and thus improved images of the tissue ... to maximize the detail in the information collected" is only half true. While it is true that the asserted motivation does generally result in more information collected, the detail in the information collected is simply different, thus the image resolution of the tissue is not generally increased.

Moreover, as noted above, the exact impact of trying a wide range of frequencies was unknown for thermal acoustics prior to the present invention, except for the obvious computational complexity which by itself would strongly teach way from its consideration as taught by Kruger who teaches improvement over Bowen (narrow pulsed-based thermal acoustics) by instead using *continuous, periodically modulated radiation in place of narrowly pulsed radiation because:*

> Continuous radiation can be used to stimulate sonic waves continuously without having to wait for sequences of pulses. The localizing method for reconstructing uses constructive and destructive interference of periodic sonic waves generated by the *continuous radiation*. This approach can substantially increase the signal-to-noise ratio of the recorded signal, reduce the power requirements of the radiation source, and simplify the reconstruction methodology and the complexity of the associated apparatus.

Accordingly, although unlike Van Veen Kruger has some relation to the claimed invention as it relates to thermoacoustic imaging, Kruger teaches a method of examining biological tissue using continuous radiation at a single frequency . Moreover, as demonstrated above, Kruger clearly teaches away from the claimed method of examining biological tissue comprising radiating a tissue region with a plurality of microwave radiation pulses, such as Applicants' claimed pulses which span a range of microwave frequencies, such as the claimed at

least 600 MHz. Therefore, Applicants submit that amended claims 1 and 10 and their respective dependent claims are patentable over Kruger in view of Van Veen.

Although clearly not bound by the opinion of foreign examiners, Applicants have provided a copy of the Search Report/Written Opinion rendered by the EPO. The cited references included Kruger (referred to as D2) and Wang (referred to as D1). Inventive step was found for all claims (same as pending claims herein). Reasons for such finding are copied below:

> Reference is made to the following documents:
> D1: US6567688 B
> D2: US6104942 A
>
> Document D1, which is considered to represent the most relevant state of the art, discloses a method and apparatus for examining biological tissue by scanning electromagnetically-induced thermoacoustic tomography.
>
> The subject-matter of the independent claims 1 and 10 differs in that the tissue region is radiated with a plurality of microwave radiation pulses, said plurality of radiation pulses spanning a range of microwave frequencies of at least 600 MHZ.
>
> This difference forms a solution to the problem of enhancing thermoacoustic imaging of biological tissue, e.g. gathering more information about tissue regions and permitting detection of smaller tumors.

> Contrary to the current independent claims, document D1 teaches use of a single microwave pulse frequency generally in the range from 300 MHz to 3 Ghz (D1, col. 5, lines 22-30).
>
> Document D2 teaches two embodiments for imaging: thermoacoustic (see especially D2, col. 3, lines 12-21) and absorption spectrum (see especially D2, col. 3, lines 22-30). In both embodiments, continuos periodically modulated radiation is employed (see also D2, col. 2, line 66-col. 3, line 11). Furthermore, document D2 only teaches a narrowband frequency range and seems not to disclose or suggest forming an image from thermoacoustic signals obtained by using a range of stimulating frequencies. In the single embodiment where document D2 does disclose sweeping of the microwave frequency (e.g. D2, col. 5, line 60-col. 6, line 11), there is no hint to the use of an ultrawideband frequency range of at least 600 MHz.

The specific features of the solution provided by claim 1 are neither disclosed in nor rendered obvious by either one of the available citations. As a consequence, the person skilled in the art, who set off to solve the aforementioned problem starting from the disclosure of document D1 or D2, would not find any indications or prompts in the available prior art documents to modify the method and system for examining biological tissue in the way set out in the independent claims. The solution proposed in these claims of the present application is therefore considered as involving an inventive step.

Applicants have made every effort to present claims which distinguish over the cited art, and it is believed that all claims are clearly in condition for allowance. However, Applicants invite the Examiner to call the undersigned if it is believed that a telephonic interview (direct line (561) 671-3662) would expedite the prosecution of the application to an allowance. Although no fee is believed to be due, the Commissioner for Patents is hereby authorized to charge any deficiency in fees due or credit an excess in fees with the filing of the papers submitted herein during prosecution of this application to Deposit Account No. 50-0951.

Respectfully submitted,

AKERMAN SENTERFITT

Date: June 2, 2006

Neil R. Jetter
Registration No. 46,803
P.O. Box 3188
West Palm Beach, FL 33402-3188
Tel: 561-653-5000

Docket No. 5853-376

# PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Jetter, Nell R.
AKERMAN SENTERFITT
222 Lakeview Avenue, 400
West Palm Beach, FL 33402
ETATS-UNIS D'AMERIQUE

# PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(PCT Rule 71.1)

| | |
|---|---|
| Date of mailing *(day/month/year)* | 03.02.2006 |
| Applicant's or agent's file reference | IMPORTANT NOTIFICATION |
| 5853-376WO | |

| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
|---|---|---|
| PCT/US2004/036670 | 03.11.2004 | 17.11.2003 |

Applicant
UNIVERSITY OF FLORIDA ET AL.

FEB - 6 2006

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary report on patentability and its annexes, if any, established on the International application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary report on patentability. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed invention is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

| Name and mailing address of the international preliminary examining authority: | Authorized Officer |
|---|---|
| European Patent Office - P.B. 5818 Patentlaan 2<br>NL-2280 HV Rijswijk - Pays Bas<br>Tel. +31 70 340 - 2040 Tx: 31 651 epo nl<br>Fax: +31 70 340 - 3016 | Viegas da Cruz, I<br>Tel. +31 70 340-1923 |

Form PCT/IPEA/416 (January 2004)

# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference 5853-376WO | FOR FURTHER ACTION | See Form PCT/IPEA/416 |
|---|---|---|
| International application No PCT/US2004/036670 | International filing date (day/month/year) 03.11.2004 | Priority date (day/month/year) 17.11.2003 |

International Patent Classification (IPC) or national classification and IPC
A61B5/05

Applicant
UNIVERSITY OF FLORIDA ET AL

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 3 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☐ Box No. VIII Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 14.09.2005 | 09.02.2006 |

Name and mailing address of the international preliminary examining authority:
European Patent Office - P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040 Tlx 31 651 epo nl
Fax: +31 70 340 - 3016

Authorized Officer
Lommel, A
Telephone No. +31 70 340-4230

Form PCT/IPEA/409 (Cover Sheet) (January 2004)

# INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/US2004/036670

## Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

**Description, Pages**

1-22 as originally filed

**Claims, Numbers**

1-15 filed with the demand

**Drawings, Sheets**

1/3-3/3 as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

**INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY**

International application No.
PCT/US2004/036670

**Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-15 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 1-15 |
| | No: | Claims | |
| Industrial applicability (IA) | Yes: | Claims | 1-15 |
| | No: | Claims | |

2. Citations and explanations (Rule 70.7):

see separate sheet

**INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY (SEPARATE SHEET)**

International application No.
PCT/US2004/036670

Re Item V
**Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

Reference is made to the following documents:
D1: US6567688 B
D2: US6104942 A

Document D1, which is considered to represent the **most relevant state of the art**, discloses a method and apparatus for examining biological tissue by scanning electromagnetically-induced thermoacoustic tomography.

The **subject-matter of the independent claims 1 and 10 differs in that** the tissue region is radiated with a plurality of microwave radiation pulses, said plurality of radiation pulses spanning a range of microwave frequencies of at least 600 MHZ.

This **difference forms a solution to the problem of** enhancing thermoacoustic imaging of biological tissue, e.g. gathering more information about tissue regions and permitting detection of smaller tumors.

Contrary to the current independent claims, document D1 teaches use of a single microwave pulse frequency generally in the range from 300 MHz to 3 Ghz (D1, col. 5, lines 22-30).

Document D2 teaches two embodiments for imaging: thermoacoustic (see especially D2, col. 3, lines 12-21) and absorption spectrum (see especially D2, col. 3, lines 22-30). In both embodiments, continuos periodically modulated radiation is employed (see also D2, col. 2, line 66-col. 3, line 11). Furthermore, document D2 only teaches a narrowband frequency range and seems not to disclose or suggest forming an image from thermoacoustic signals obtained by using a range of stimulating frequencies. In the single embodiment where document D2 does disclose sweeping of the microwave frequency (e.g. D2, col. 5, line 60-col. 6, line 11), there is no hint to the use of an ultrawideband frequency range of at least 600 MHz.

**INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY (SEPARATE SHEET)**

International application No.
PCT/US2004/036670

The specific features of the solution provided by claim 1 are neither disclosed in nor rendered obvious by either one of the available citations. As a consequence, the person skilled in the art, who set off to solve the aforementioned problem starting from the disclosure of document D1 or D2, would not find any indications or prompts in the available prior art documents to modify the method and system for examining biological tissue in the way set out in the independent claims. The solution proposed in these claims of the present application is therefore considered as **involving an inventive step.**

[SUBSTITUTE SHEET]

CLAIMS

We claim:

1. A method of examining biological tissue, comprising the steps of:

radiating a tissue region with a plurality of microwave radiation pulses, said plurality of radiation pulses spanning a range of microwave frequencies of at least 600 MHz, wherein said tissue region emits a plurality of thermoacoustic signals responsive to said plurality of microwave pulses, and

forming at least one image of said tissue region from said plurality of thermoacoustic signals.

2. The method of claim 1, wherein said tissue region comprises breast tissue.

3. The method of claim 2, wherein said at least one image of said breast tissue comprises a plurality of said images, said plurality of images from fractional portions of said breast, further comprising the step of combining said images from said local regions to form an overall image of said breast.

4. The method of claim 1, wherein said frequency range is at least 1 GHz.

5. The method of claim 1, wherein said step of forming at least one image comprises adaptive beamforming.

[SUBSTITUTE SHEET]

6. The method of claim 5, wherein said adaptive beamforming comprises the steps of:

providing a sensor array including a plurality of sensor elements, wherein an array steering vector corresponding to a signal of interest (SOI) is unknown;

representing said array steering vector with an ellipsoidal uncertainty set;

bounding a covariance fitting relation for said array steering vector with said uncertainty ellipsoid, and

solving said matrix fitting relation to provide an estimate of said array steering vector.

7. The method of claim 1, wherein said pulses include a plurality of different polarizations.

8. The method of claim 1, further comprising the step of pattern recognition from said image.

9. The method of claim 8, wherein said step of pattern recognition comprises adaptive signal processing.

10. A system for examining biological tissue, comprising:

a microwave radiation source for radiating a tissue region with a plurality of microwave radiation pulses, said plurality of radiation pulses spanning a range of microwave

frequencies of at least 600 MHz, wherein said tissue region emits a plurality of thermoacoustic signals responsive to said microwave pulses;

an acoustic transducer array for receiving said thermoacoustic signals, said transducer array providing electrical signals in response thereto, and

an imager for forming at least one image of said tissue region from said electrical signals.

11. The system of claim 10, further comprising at least one horn antenna coupled to said microwave radiation source for emanating said plurality of microwave pulses.

12. The system of claim 11, further comprising structure for translating at least one of said transducer array and said antenna.

13. The system of claim 10, wherein said frequency range is at least 1 GHz.

14. The system of claim 10, wherein said microwave radiation source generates ultrawideband signals.

15. The system of claim 10, wherein said pulses include a plurality of different polarizations.